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RESPONSE TO NITROGEN, PHOSPHORUS, POTASSIUM AND SULPHUR IN GROWTH AND QUALITY OF CABBAGE

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Abstract

A field experiment was carried out at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during October 2009 to May 2010 to evaluate the response of cabbage to N, P, K and S as the source of urea, TSP, MP and gypsum application in Salna silty clay loam soil. Treatment receiving 240N: 45 P: 180 K and 45S kg/ha performed best in respect of plant height, leaf length and breadth and thickness of head of cabbage while 240N: 45 P: 180 K: 60 S kg/ha recorded highest calcium (0.7867%) and sulphur (1.423%) content in loose leaves but magnesium (0.1700%) in the treatment of 240 N: 45 P: 180 K: 45S kg /ha. The later treatment also recorded the maximum Ca (0.6967%), Mg (0.1530%) and S (1.1830%) in heading leaves. Treatment 320 N: 45 P: 180 K: 30 S kg showed maximum iron, manganese and zinc content both in loose and heading leaves of the crop. Nitrogen (163.30 kg/ha), phosphorus (5.63 kg/ha), potassium (18.35 kg/ha) and sulphur (32.60 kg/ha) uptake by plant was the highest in treatment receiving 240 N: 45 P: 180 K and 45 S kg/ha.

Introduction

Cabbage belongs to the Cruciferae family and is related to turnips, cauliflowers and brussels sprouts. Cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most important winter vegetables grown in Bangladesh which contains vitamins and minerals (Quayyum and Akanda, 1988). It is an herbaceous rapid growing vegetable. This unique vegetable has been widely grown in both tropical and temperate regions of the world (Sarker *et al.*, 2002). Cabbage ranks the second position in respect of production and area among the vegetables grown in Bangladesh. Kustia, Meherpur, Jessore, Bogra and Tangail are leading cabbage growing districts in Bangladesh (Sarker *et al.*, 2002). There were 12060 hectares of land under cabbage cultivation with a production of 113 thousand metric tons in the country during the year 1997-98 (Anon. 1999) with an average yield of 9.29 t/ha which is quite low in comparison with other countries of the world like South Korea (11.7 t/ha), Germany (54.61 t/ha), Japan (40.32 t/ha) and India (19.12 t/ha) (FAO, 1998).

The importance of nitrogen, phosphorus, potassium and sulphur on the growth and yield of vegetable crops is well established. Among the nutrients, nitrogen plays the most important role

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for vegetative growth of the crop. Phosphorus is also essential nutrient element which helps in the good growth of the roots of vegetable crops. Phosphorus helps in the root development and increases the efficiency of leaf in the manufacture of sugar. Potassium exerts balancing role on the effects of both nitrogen and phosphorus, consequently it is especially important in multinutrient fertilizer application (Brady, 1990). Analysis of soil samples of important soil types and series of Bangladesh reveals that 80-90% soils are poor in zinc and sulphur, while 100% soils are deficit in nitrogen (Porch and Islam, 1984). Besides this deficiency in phosphorus is now considered as one of the major constraint to successful production of upland crops (Islam and Noor, 1982). Moreover, the proportion of nutrient applied by vegetable growers in Bangladesh is not balanced. Use of imbalanced nutrients in the soils may be harmful and causing the agricultural soil degraded and unproductive (Hossain *et al.*, 2004). Thus, the nutrient deficient soils must be identified and these soils should be enriched with these nutrients through balanced use of fertilizer. Keeping these facts in mind to find out the optimum doses of N, P, K and S nutrients for sustainable growth and nutritional quality and to assess nutrient uptake by cabbage in Salna silty clay loam soil of cabbage by the application of appropriate doses of N, P, K, and S nutrients.

Materials and Methods

A field experiment was conducted at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during October 2009 to May 2010 to find out the maximum growth and quality of cabbage by the application of judicial doses of nitrogen, phosphorus, potassium and sulphur nutrients. The soil belongs to Shallow Red Brown Terrace Salna series representing the AEZ - 28 of Madhupur Tract in Bangladesh which falls under Inceptisols in Soil Taxonomy (Brammer, 1978). Soil samples of the experimental plots were collected before transplanting seedlings of cabbage from a depth of 0-15 cm and analyzed for physical and chemical properties in the Soil Science laboratory. The soil was silty clay loam in texture with a pH 6.70, bulk density 1.42 g/cc, particle density 2.59 g/cc, organic carbon 0.75%, total N 0.11%, available P 11.00 ppm, exchangeable K 0.25 meq/100 g soil, available S 9.40 ppm, available Zn 1.30 ppm and available B 0.20 ppm in the surface.

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 2 m × 3 m maintaining line to line 60 cm and seedling to seedling 40 cm which were separated by 0.5 m drain. The plots were raised by 30 cm by raising soil from the drain. There were eighteen treatment combinations selected on the basis of nutrient status of the initial soil of the experimental field viz. $T_1 = N_0P_{45}K_{180}S_{30}$, $T_2 = N_{80}P_{45}K_{180}S_{30}$, $T_3 = N_{160}P_{45}K_{180}S_{30}$, $T_4 = N_{240}P_{45}K_{180}S_{30}$, $T_5 = N_{320}P_{45}K_{180}S_{30}$, $T_6 = N_{240}P_0K_{180}S_{30}$, $T_7 = N_{240}P_{15}K_{180}S_{30}$, $T_8 = N_{240}P_{30}K_{180}S_{30}$, $T_9 = N_{240}P_{60}K_{180}S_{30}$, $T_{10} = N_{240}P_{45}K_0S_{30}$, $T_{11} = N_{240}P_{45}K_{60}S_{30}$, $T_{12} = N_{240}P_{45}K_{120}S_{30}$, $T_{13} = N_{240}P_{45}K_{240}S_{30}$, $T_{14} = N_{240}P_{45}K_{180}S_0$, $T_{15} = N_{240}P_{45}K_{180}S_{15}$, $T_{16} = N_{240}P_{45}K_{180}S_{45}$, $T_{17} = N_{240}P_{45}K_{180}S_{60}$ and $T_{18} = N_0P_0K_0S_0$ kg/ha.

The soil was well prepared by deep ploughing with tractor followed by harrowing and laddering up to a good tilth. The experimental plot was laid in south north facing and all weeds and stubbles were removed. The individual plots were made by making ridges (25 cm height) from the soil surface. Ridges were made around each plot to restrict the lateral run off irrigation water. The hybrid variety Autumn Queen of cabbage was used. The required fertilizers were added to the individual plot. Ten plants were selected randomly from each plot for data

collection at the mature stage. The mature stage was determined visually by seeing the opening of two outside inner leaf. Dried loose and heading leaves were ground and processed for determination of N, P, K, Ca, Mg, S, Fe, Mn and Zn contents. The recorded data on various parameters of the crop were statistically analyzed and the differences between the treatment means were compared by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Plant height

The effect of nitrogen, phosphorus, potassium and sulphur on plant height of cabbage was significant (Table 1). The maximum plant height (37.47 cm) was recorded by the treatment T_{16} receiving 240 N: 45 P: 180 K: 45 S kg/ha. The increased plant height in broccoli by the application of 240 N: 100 P: 80 K kg/ha also reported by Moniruzzaman *et al.* (2006). Similar results were shown by Sarker *et al.* (2002) in cabbage. The effect of this treatment was statistically similar to all other treatments except T_1, T_2, T_3, T_6, T_{10}, T_{14} and T_{18}. The minimum height of plant (16.44 cm) was found in control plots. The results are in agreement with those of Anwar *et al.* (2001). They observed that plant height was (37.70, 40.50 cm) by the application of 34 P:66 K:20 S: 1 Mo kg/ha. Sarker *et al.* (1996) noted significant difference in plant height of cabbage due to different sources of nutrients. Kacjan Marsic and Osvald (2004) found that plant height of white cabbage was significantly increased when 30% of total N was pre-plant incorporated and remaining N and total amounts of P and K were applied via fertigation.

Leaf length

Leaf length had significantly influenced by different doses of nutrients (Table 1). The maximum leaf length (34.36 cm) was noted by T_{16} receiving 240 N: 45 P: 180 K:45 S Kg/ha which was statistically similar to T_4, T_7, T_8, T_9, T_{11}, T_{12}, T_{13}, T_{15} and T_{17}. This might be due to the favourable influence of nitrogen, phosphorus, potassium and sulphur resulting increased leaf length of cabbage. The minimum value (19.08 cm) was observed in T_{18} (control) treatment. Anwar *et al.* (2001) recorded significantly increased leaf length of broccoli with the increasing rates of nitrogen upto 150 kg/ha along with 34 P: 66 K: 20S: 1 kg Mo: 5 Zn Kg /ha plus 5 t/ha cowdung.

Leaf breadth

Different nutrient levels significantly influenced leaf breadth of cabbage (Table 1). The maximum leaf breadth (27.00 cm) was recorded in T_{16} treatment which was similar to T_4 and T_8 treatments and the minimum leaf breadth (14.17 cm) was obtained in control treatment (T_{18}). The effects of treatments T_3, T_7, T_8, T_9, T_{11}, T_{12} and T_{17} were similar in recording leaf breadth of cabbage. Leaf breadth significantly increased up to 240 N: 45 P: 180 K: 45 S Kg/ha. Further, increasing nutrient levels decreased leaf breadth of cabbage. Moniruzzaman *et al.* (2006) reported significantly higher leaf breadth of broccoli with 240 N,: 43 P: 66K Kg/ha.

Thickness of head

There was a significant effect of different levels of nutrients in recording thickness of cabbage (Table 1). The maximum thickness of head (12.62 cm) was recorded in T_{16} treatment which was statistically similar to the rest of the treatments except T_1, T_2, T_3, T_6, T_{10}, T_{14}, T_{15}, T_{17} and T_{18}. The minimum thickness (7.04 cm) was recorded in T_{18} (control) treatment. Application

of different combinations of nutrients (T_{16}) led to 79.26% higher thickness of head over control treatment. Thickness of head significantly increased with the increase of N from 0 to 240 kg, P from 0 to 45 kg, K from 0 to 180 kg and S from 0 to 45 kg/ha. Sarker *et al.* (2002) reported that the maximum thickness of head of cabbage (14.55 cm) was noted with organic + inorganic fertilizer application.

Table 1. Effects of different doses (kg/ha) of nutrients on plant height, leaf length, leaf breadth and thickness of head of loose and heading leaves of cabbage

Treatments	Plant height (cm)	Leaf length (cm)	Leaf breadth (cm)	Thickness of head (cm)
$T_1 = N_0P_{45}K_{180}S_{30}$	27.80c	24.78cd	19.67h	9.77d
$T_2 = N_{80}P_{45}K_{180}S_{30}$	30.90bc	26.20bc	23.94cd	10.70bcd
$T_3 = N_{160}P_{45}K_{180}S_{30}$	30.95bc	26.70bc	25.17bc	10.72bcd
$T_4 = N_{240}P_{45}K_{180}S_{30}$	37.22a	32.78ab	26.66a	12.17ab
$T_5 = N_{320}P_{45}K_{180}S_{30}$	33.71ab	26.50bc	22.28ef	11.23abcd
$T_6 = N_{240}P_0K_{180}S_{30}$	30.89bc	24.85cd	20.67gh	10.44cd
$T_7 = N_{240}P_{15}K_{180}S_{30}$	35.30ab	28.22abc	24.67bc	11.67abc
$T_8 = N_{240}P_{30}K_{180}S_{30}$	36.72a	31.01abc	26.04ab	11.97abc
$T_9 = N_{240}P_{60}K_{180}S_{30}$	33.92ab	27.66abc	24.70bc	11.39abc
$T_{10} = N_{240}P_{45}K_0S_{30}$	30.70bc	26.14bc	20.83fgh	10.50cd
$T_{11} = N_{240}P_{45}K_{60}S_{30}$	33.60ab	27.34abc	24.65bc	11.70abc
$T_{12} = N_{240}P_{45}K_{120}S_{30}$	35.44ab	28.35abc	24.81bc	11.80abc
$T_{13} = N_{240}P_{45}K_{240}S_{30}$	34.75ab	28.08abc	24.03cd	11.58abc
$T_{14} = N_{240}P_{45}K_{180}S_0$	30.97bc	26.73bc	21.17fg	10.60cd
$T_{15} = N_{240}P_{45}K_{180}S_{15}$	33.55ab	27.07abc	21.72efg	10.65bcd
$T_{16} = N_{240}P_{45}K_{180}S_{45}$	37.47a	34.36a	27.00a	12.62a
$T_{17} = N_{240}P_{45}K_{180}S_{60}$	33.03ab	27.00abc	24.68bc	10.75bcd
$T_{18} = N_0P_0K_0S_0$	16.44d	19.08d	14.17i	7.04e
CV (%)	7.25	5.46	3.54	8.75

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT

Calcium content in loose leaves

There was a significant difference in recording calcium content of loose leaves of cabbage due to the application of nitrogen, phosphorus, potassium and sulphur (Table 2). Treatment T_{17} receiving 240 N: 45 P: 180 K: 60 S kg/ha recorded the maximum calcium content in loose leaves (0.7867%) which was statistically superior to the rest of the treatments. The lowest calcium content (0.3200%) in loose leaves was found in control treatment (T_0). Different levels of nitrogen, phosphorus, potassium and sulphur significantly affected calcium content in loose leaves. However, treatment T_{17} led to increase 145.84% higher calcium content than absolute control treatment (T_{18}). Wiebe *et al.* (1977) found greater Ca accumulation in loose leaves of cabbage (*Brassica oleracea* var. *capitata* L.) when compared to the heading leaves. The author attributes high Ca accumulation with greater transpiration rates in loose leaves of cabbage.

Magnesium content in loose leaves

Magnesium content in loose leaves was significantly influenced by different levels of nutrients (Table 2). The highest magnesium content in loose leaves (0.1700%) was noted in T_{16} treatment which was statistically similar to all the treatments except T_{18}. Higher magnesium content in loose leaves might be due to favourable influence of nitrogen, phosphorus, potassium and sulphur in cabbage. The lowest magnesium (0.1520%) content in loose leaves was noted in absolute control treatment.

Sulphur content in loose leaves

Different levels of nutrients markedly influenced sulphur content in loose leaves of cabbage (Table 2). Gradual increment in sulphur level along with nitrogen, phosphorus and potassium nutrients significantly increased sulphur content in loose leaves of cabbage. This might be due to the favaourable influence of sulphur nutrients along with nitrogen, phosphorus and potassium resulting higher content of sulphur. Application of 240 N: 45 P:180 K:60 S kg/ha (T_{17}) recorded the highest sulphur content in loose leaves which was statistically similar to T_{16} treatment but superior to the rest of the treatments. The lowest sulphur content in loose leaves was found in absolute control treatment (T_{18}).

Iron content in loose leaves

Iron content in loose leaves was markedly influenced by different levels of nutrients (Table 2). The highest iron content (0.4133%) in loose leaves was noted in T_5 treatment which was statistically similar to all the treatments except T_1, T_2, T_6, T_{10} and T_{18} treatments. The lowest iron content (0.2767%) was found in T_{18} (Control) treatment.

Manganese content in loose leaves

There were significant variations among the treatments in respect of manganese content in loose leaves of cabbage (Table 2). The maximum manganese content in loose leaves (0.3500%) was observed in T_5 treatment which was statistically similar to all treatments except T_1, T_2, T_3, T_{10}, T_{14} and T_{18}. The lowest manganese content (0.1820%) in loose leaves was attained in absolute control treatment (T_{18}).

Zinc content in loose leaves

Zinc content in loose leaves was significantly influenced by different levels of nutrients (Table 2). The maximum zinc content (0.0350%) in loose leaves was found in T_5 receiving 320 N: 45 P: 180: K: 30 S Kg/ha which was statistically similar to all the treatments except T_{18}. The minimum zinc content (0.0260%) in loose leaves was found in control (T_{18}) treatment.

Table 2. Effects of different doses (kg/ha) of nutrients on calcium, magnesium, sulphur, iron, manganese and zinc content in loose leaves of cabbage

Treatments	Ca content (%)	Mg content (%)	S content (%)	Fe content (%)	Mn content (%)	Zn content (%)
$T_1 = N_0P_{45}K_{180}S_{30}$	0.4600d	0.1580ab	0.671h	0.3050b	0.1980c	0.0280ab
$T_2 = N_{80}P_{45}K_{180}S_{30}$	0.5467c	0.1667a	1.023cd	0.3010b	0.2025b	0.0280abc
$T_3 = N_{160}P_{45}K_{180}S_{30}$	0.5567c	0.1600ab	1.077c	0.3533ab	0.2000b	0.0280abc
$T_4 = N_{240}P_{45}K_{180}S_{30}$	0.5467c	0.1633ab	1.053cd	0.3467ab	0.2900a	0.0290ab
$T_5 = N_{320}P_{45}K_{180}S_{30}$	0.5400c	0.1625ab	0.950def	0.4133a	0.3500a	0.0350a
$T_6 = N_{240}P_0K_{180}S_{30}$	0.4100d	0.1629ab	0.836g	0.3020b	0.3000a	0.02920ab
$T_7 = N_{240}P_{15}K_{180}S_{30}$	0.5900c	0.1633ab	1.027cd	0.3567ab	0.2955a	0.0293ab
$T_8 = N_{240}P_{30}K_{180}S_{30}$	0.5733c	0.1624ab	1.010cd	0.3367ab	0.2933a	0.0293ab
$T_9 = N_{240}P_{60}K_{180}S_{30}$	0.5533c	0.1599ab	0.976cde	0.3633ab	0.3100a	0.0290ab
$T_{10} = N_{240}P_{45}K_0S_{30}$	0.4067d	0.1590ab	0.866fg	0.3030b	0.2180b	0.0291ab
$T_{11} = N_{240}P_{45}K_{60}S_{30}$	0.5733c	0.1667a	0.950def	0.3600ab	0.3033a	0.0330a
$T_{12} = N_{240}P_{45}K_{120}S_{30}$	0.5367c	0.1667a	1.183b	0.3533ab	0.2833a	0.0280abc
$T_{13} = N_{240}P_{45}K_{240}S_{30}$	0.5900c	0.1567ab	1.043cd	0.3533ab	0.2933a	0.0290ab
$T_{14} = N_{240}P_{45}K_{180}S_0$	0.3333e	0.1620ab	0.683h	0.3533ab	0.2200b	0.0290ab
$T_{15} = N_{240}P_{45}K_{180}S_{15}$	0.4133d	0.1626ab	0.900efg	0.3600ab	0.2900a	0.0296ab
$T_{16} = N_{240}P_{45}K_{180}S_{45}$	0.7612b	0.1700a	1.397a	0.3600ab	0.3400a	0.0296ab
$T_{17} = N_{240}P_{45}K_{180}S_{60}$	0.7867a	0.1670a	1.423a	0.3167ab	0.3067a	0.0346a
$T_{18} = N_0P_0K_0S_0$	0.3200e	0.1520b	0.453i	0.2767b	0.1820c	0.0260b
CV (%)	5.81	10.01	6.61	10.38	4.22	9.72

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT

Calcium content in heading leaves

Calcium content in heading leaves was significantly influenced by different levels of nitrogen, phosphorus, potassium and sulphur nutrients (Table 3). The highest calcium content in heading leaves (0.7300%) was noted in T_{17} which was statistically similar to T_{16} but superior to the rest of the treatments. This might be due to the influence of sulphur fertilizer as gypsum which contains calcium that led to increase calcium content in the heading leaves of cabbage. The lowest calcium content (0.0533%) was found in absolute control treatment (T_{18}).

Magnesium content in heading leaves

The effects of different levels of nitrogen, phosphorus, potassium and sulphur nutrients on magnesium content in heading leaves are presented in Table 3. There were significant variations among the treatments in respect of magnesium content in heading leaves. The highest magnesium content in heading leaves (0.1530%) was noted in T_{16} treatment which was statistically similar to all the treatments except T_1, T_2, T_{10}, T_{14} and T_{18}. The lowest magnesium content (0.1300%) in heading leaves was observed in control (T_{18}).

Sulphur content in heading leaves

Different nutrients significantly influenced sulphur content in heading leaves of cabbage (Table 3). The highest sulphur content (1.2000%) in heading leaves was attained in T_{17} treatment which was statistically similar to T_{16} but superior to the rest of the treatments. The higher sulphur content in heading leaves was found in T_{17} might be due to the prevalence of comparatively higher supply of sulphur from previously applied gypsum fertilizer. The lowest sulphur content (0.2567%) in heading leaves was found in control (T_{18}).

Iron content in heading leaves

Different treatments reflected significantly in terms of iron content in heading leaves of cabbage (Table 3). The highest iron content (0.300%) in heading leaves was noted in T_5. The effect of this treatment was statistically similar to all the treatments except T_1 and T_{18} treatments. This might be due to the application of higher dose of chemical nitrogen fertilizer which might have increased acidity result higher solubility as well as more iron content in heading leaves of the crop. The lowest iron content (0.2010%) in heading leaves was found in control (T_{18}).

Manganese content in heading leaves

The effects of different nutrients on manganese content in heading leaves of cabbage were significant (Table 3). The maximum manganese content (0.2333%) in heading leaves was noted in T_5 treatment. The effect of treatment T_5 was however, statistically similar to all the treatments except T_1, T_2, T_3 and T_{18} treatments. This might be due to the higher dose of inorganic nitrogen fertilizer which might fall of soil pH result higher solubility as well as more manganese content in heading leaves of the crop. The lowest manganese content (0.1710%) was found in T_{18} (control) treatment.

Zinc content in heading leaves

Application of different levels of nutrients influenced zinc content in heading leaves of cabbage (Table 3). The highest zinc content (0.0315%) in heading leaves was recorded in T_5

treatment which was statistically similar to all the treatments except T_1 and T_{18} treatments. The lowest zinc content (0.0212%) in heading leaves was found in control treatment (T_{18}).

Table 3. Effects of different doses (kg/ha) of nutrients on calcium, magnesium, sulphur, iron, manganese and zinc content in heading leaves of cabbage

Treatments	Ca content (%)	Mg content (%)	S content (%)	Fe content (%)	Mn content (%)	Zn content (%)
$T_1 = N_0P_{45}K_{180}S_{30}$	0.1500g	0.1390b	0.5167h	0.2204bc	0.1800b	0.022b
$T_2 = N_{80}P_{45}K_{180}S_{30}$	0.2167defg	0.1400b	0.7800cde	0.2550ab	0.1804b	0.0263ab
$T_3 = N_{160}P_{45}K_{180}S_{30}$	0.2433def	0.1420ab	0.8600bcd	0.2567ab	0.1805b	0.0260ab
$T_4 = N_{240}P_{45}K_{180}S_{30}$	0.2533def	0.1422ab	0.8667bc	0.2600ab	0.2133ab	0.0263ab
$T_5 = N_{320}P_{45}K_{180}S_{30}$	0.2700d	0.1423ab	0.7567def	0.3000a	0.2333a	0.0315a
$T_6 = N_{240}P_0K_{180}S_{30}$	0.1833efg	0.1392ab	0.6267g	0.2560ab	0.2200ab	0.0260ab
$T_7 = N_{240}P_{15}K_{180}S_{30}$	0.2533def	0.1430ab	0.7867cde	0.2500ab	0.2200ab	0.0283ab
$T_8 = N_{240}P_{30}K_{180}S_{30}$	0.2667de	0.1432ab	0.8433bcd	0.2540ab	0.2133ab	0.0246ab
$T_9 = N_{240}P_{60}K_{180}S_{30}$	0.2633def	0.1430ab	0.7933cd	0.2267abc	0.2200ab	0.0263ab
$T_{10} = N_{240}P_{45}K_0S_{30}$	0.1800fg	0.1398b	0.6333g	0.2510ab	0.2210ab	0.0263ab
$T_{11} = N_{240}P_{45}K_{60}S_{30}$	0.3567c	0.1430ab	0.6700fg	0.2200abc	0.2133ab	0.0266ab
$T_{12} = N_{240}P_{45}K_{120}S_{30}$	0.4467b	0.1432ab	0.8967b	0.2167abc	0.2100ab	0.0260ab
$T_{13} = N_{240}P_{45}K_{240}S_{30}$	0.4567b	0.1428ab	0.6867efg	0.2300abc	0.2067ab	0.0260ab
$T_{14} = N_{240}P_{45}K_{180}S_0$	0.0666h	0.1391b	0.7867cde	0.2500ab	0.2215ab	0.0250ab
$T_{15} = N_{240}P_{45}K_{180}S_{15}$	0.2000defg	0.1422ab	0.5867gh	0.2530ab	0.2067ab	0.0263ab
$T_{16} = N_{240}P_{45}K_{180}S_{45}$	0.6967a	0.1530a	1.1830a	0.2400abc	0.2067ab	0.0310a
$T_{17} = N_{240}P_{45}K_{180}S_{60}$	0.7300a	0.1480ab	1.2000a	0.2520ab	0.2198ab	0.0260ab
$T_{18} = N_0P_0K_0S_0$	0.0533h	0.1300c	0.2567i	0.2010c	0.1710b	0.0212b
CV (%)	7.57	5.20	7.00	5.26	5.42	6.24

Means in a column followed by same letter (s) are not significantly different at 5% level of significance by DMRT

Nitrogen uptake by plant

Nitrogen uptake was favoured by the application of different levels of nutrients (Fig.1). The maximum nitrogen uptake (163.30 kg/ha) was noted in T_{16} receiving 240 N: 45 P: 180 K: 45S kg/ha which was statistically similar to T_5 but superior to the rest of the treatments. Treatments T_3, T_4 and T_8 were statistically similar in recording nitrogen uptake and ranked second in position. This might be due to the application of different nutrients which led to increase nitrogen uptake by cabbage. The lowest nitrogen uptake (7.58 kg/ha) was noted in T_{18} (control) treatment.

Phosphorus uptake by plant

Treatment T_{16} receiving 240 N: 45 P: 180 K: 45S kg/ha recorded the highest phosphorus uptake (5.63 kg/ha) by cabbage (Fig. 2). The effect of this treatment was statistically similar to T_9 but superior to the rest of the treatments under study. Treatments T_4 and T_8 were statistically similar in recording phosphorus uptake and ranked second in position. The lowest phosphorus uptake (0.62 kg/ha) was noted in control treatment.

Potassium uptake by plant

Effects of different nutrients on potassium uptake by cabbage were significant (Fig. 1). The maximum potassium uptake (18.35 kg/ha) by cabbage was recorded in treatment T_{16} receiving 240N: 45 P: 180 K: 45 S kg/ha. The effect of this treatment was statistically similar to T_3, T_4, T_8 and T_{13} treatments but superior to the rest of treatments. The lowest potassium uptake (3.49 kg/ha) was noted in T_{18} treatment.

Sulphur uptake by plant

Sulphur uptake by cabbage was significantly affected by the application of different nutrients (Fig. 1). Sulphur uptake varied from 2.57 to 32.60 kg /ha and the maximum sulphur uptake (32.60 kg/ha) was recorded in T_{16} which was statistically similar to T_{17} and T_4 treatments but superior to the rest of the treatments. However, all the nutrients responded significantly better than control treatment. The lowest sulphur uptake (2.57 kg/ha) was found in control treatment (T_{18}).

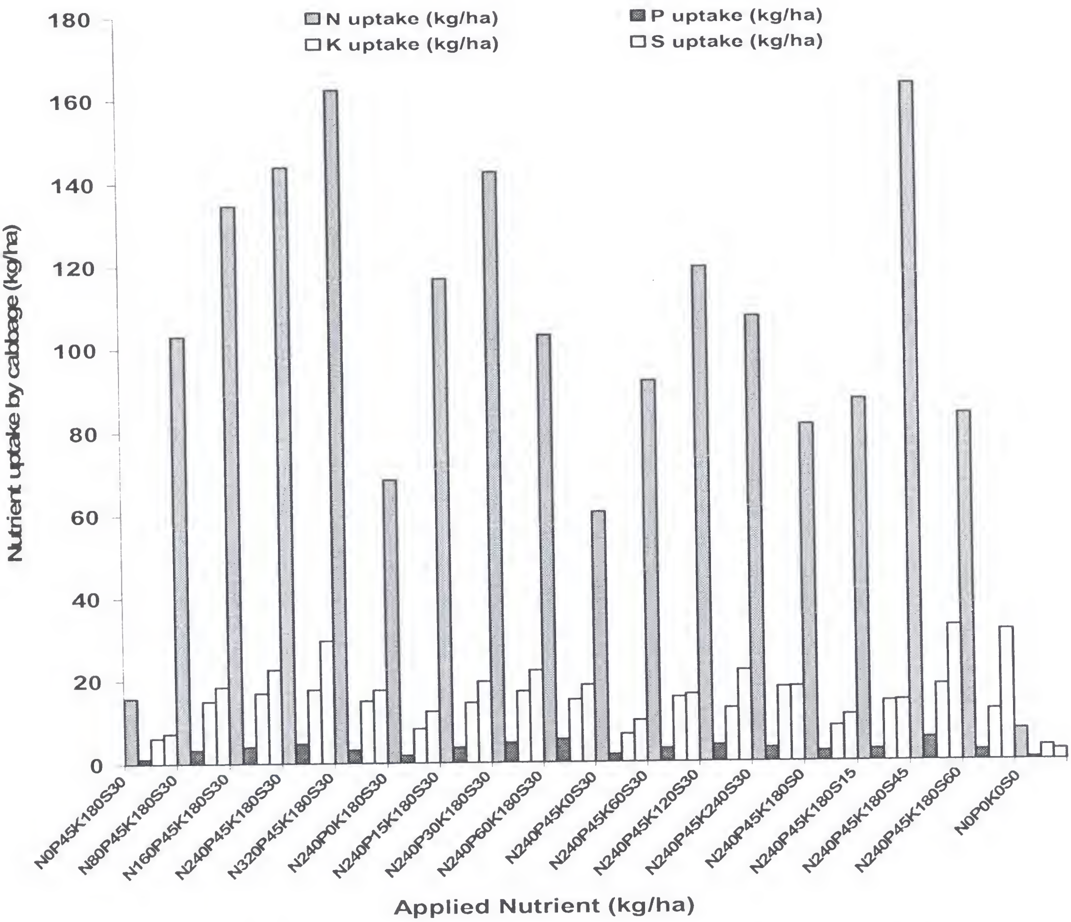

Fig. 1. Effects of different doses of nutrients on nitrogen, phosphorus, potassium and sulphur uptake by cabbage

Conclusion

Treatment receiving 240 N: 45 P: 180 K: 45 S kg/ha was the best in respect of different parameters of cabbage studied including plant height, leaf length, leaf breadth, thickness of head and Ca, Mg, S, Fe, Mn, Zn contents and N, P, K uptake by cabbage.

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